Mirror Technology for the International X-ray Observatory (iXO) Mission

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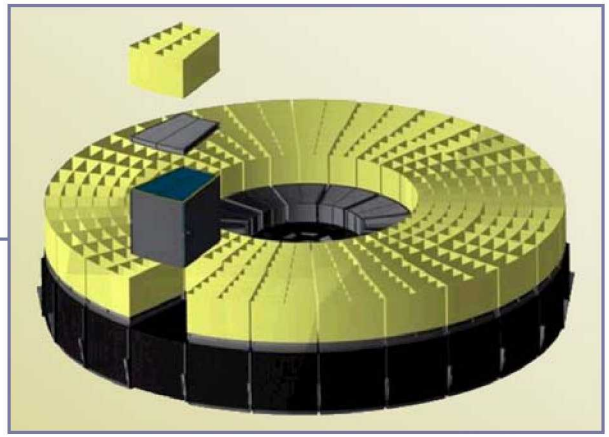
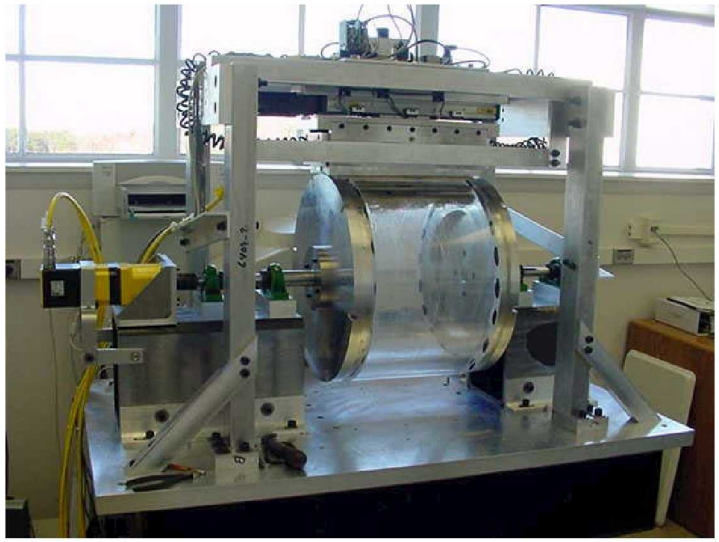


Approach to Technology Development

- **Make it (mirror segment)**
  - **Slumping (taking on the figure of the mandrel)**
  - **Cutting (getting accurate smooth edges)**
  - **Coating (maximizing reflectivity)**
- **Measure it**
  - **Suspending (letting the mirror segment be all it can be)**
  - **Measuring (completely capturing all parameters)**
- **Hold it**
  - **Suspending it and attaching it to strongback temporarily (freezing it)**
  - **Verifying figure and stress-free state (over-constrained, but not distorted)**
- **Align it**
  - **Locating it at the correct radial position**
  - **Orienting it in focus with other(s)**
- **Bond it**
  - **Permanently attaching it to housing and removing the temporary bonds**
- **Do all of these with coordination and discipline (systems engineering)**
  - **Every step done with the big picture in mind: structural, thermal, optical performance, and enabling the mirror segment to withstand launch and other hazards**

Forming Mandrels



Full Shell Mandrels: 3 pairs completed: ~2.5" HPD (two reflection)

- 485P and 485S
- 489P and 489S
- 494P and 494S

Segment Mandrels: 2 pairs being ground

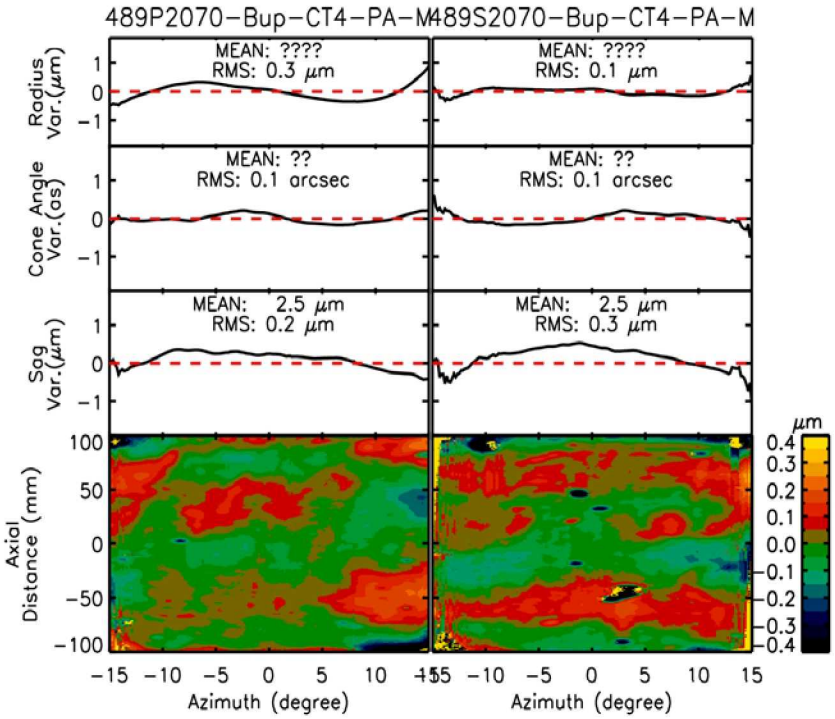
- 1480P and 1480S
- 1520P and 1520S
- Completion expected for December 2011

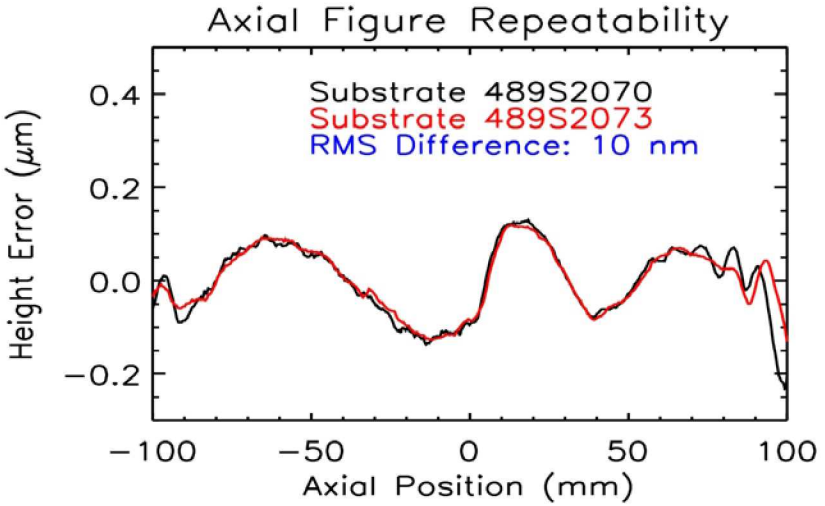
Mirror Segment Fabrication

Slumping

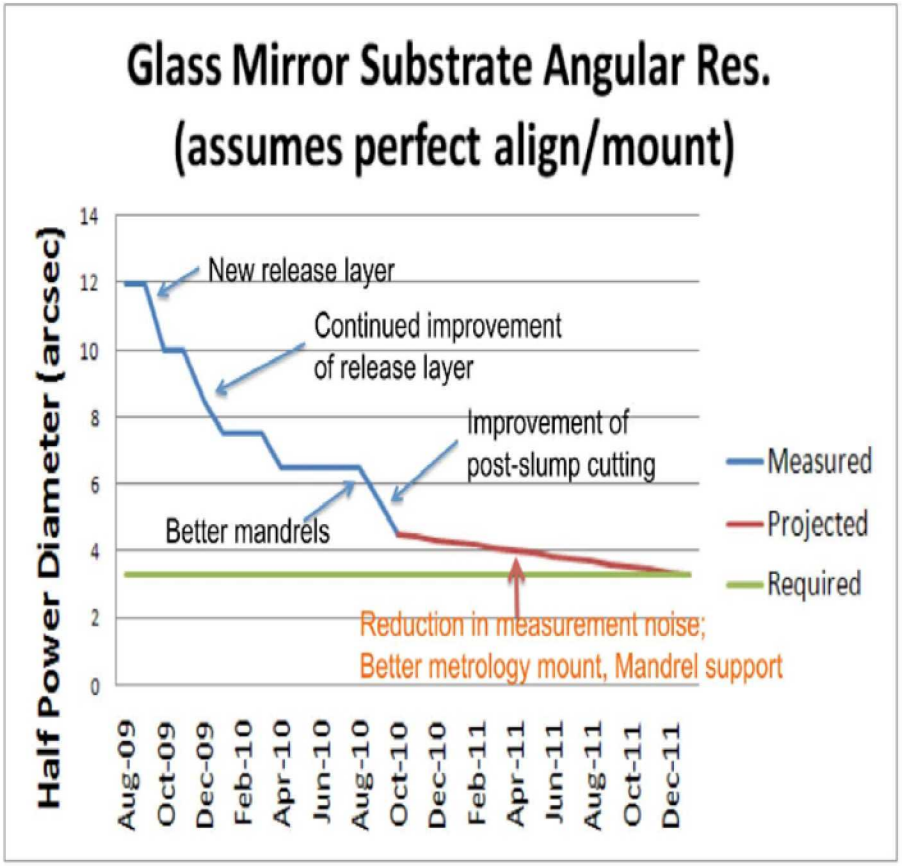
Cutting

Coating





Mirror Segment Fabrication

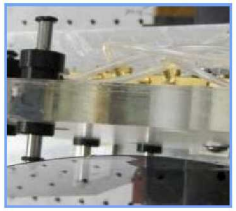


- **Best mirror substrates: 4.5" HPD (two reflection)**
- **Typical mirror substrates: 5.5" HPD (two reflection)**
- **Work to be done to meet requirements (3.3" HPD)**
  - **Better metrology, support and repeatability**
  - **Better thermal environment for metrology**
  - **Reduce distortion caused by post-slumping cutting**
  - **Better release layer application**
  - **Better mandrel support in ovens**

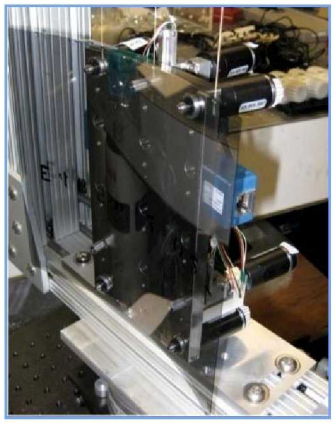
Objective: Demonstrate technique by December 2011; Demonstrate manufacture consistency by December 2012

Temporary Bonding Methods










4 Pin Air Bearing (50° mirrors)

- Hanging mirror captured on back surface by 4 pins in frictionless air bearings
- Need to transition from 50° to 30° segments in order to start with better mirrors

3 or 6 Point Edge Bond (30° mirrors)

- 1-3 flexures on top surface, 2-3 screws on bottom
- After permanent bond, de-bond of 6 temp bonds distorted mirror
- 3 point mount is being tested for less de-bond distortion

4 Point Smart Pin (30° mirrors)

- 3 suspension metrology pins steady hanging mirror (no epoxy), then bonded to 4 smart pins
- Investigating non-UV epoxy and non LDS mirror monitoring (CDS) mirror to solve thermal issues

Alignment

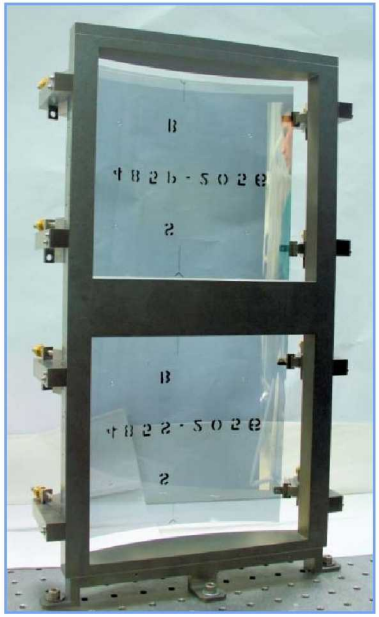
- Use two precision hexapods, one for primary and one for secondary
- 50 degree best: 1.1” HPD, 1.9” RMSd double reflection, nominally meeting requirements
- 30 degree best: 1.2” HPD, 1.7” RMSd double reflection, nominally meeting requirements
- Overall structural stability is being improved to achieve repeatability over periods of two days
  - Thermal stability
  - Mechanical stability

Permanent Bonding

Tab Bond

50° Permanent Bond Results

- **May trial: 10.9" RMSd**
  - 7 of 8 permanent bonds ≤1μm
  - Issues: R19 robot, bond procedure
- **July trial: 26.7" RMSd**
  - 5 of 8 permanent bonds ≤1μm
  - Issues: thermal, bond gap size
  - Presented results/issues at seminar
- **September trial: 10.7" RMSd**
  - 8 of 8 permanent bonds ≤1μm
  - Issues: table stability
  - Presented results/issues at seminar

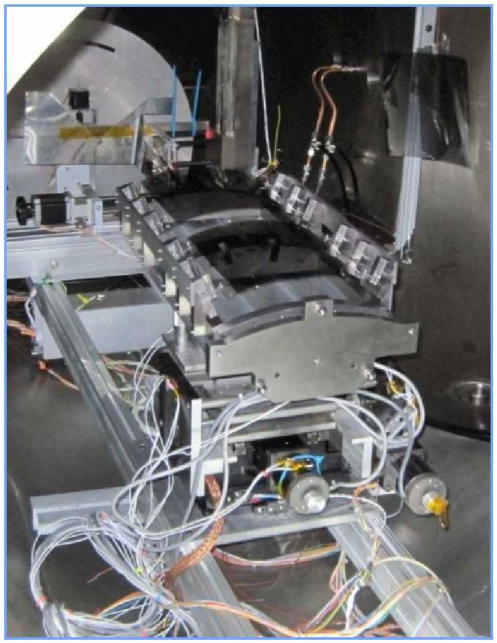


Edge Bond

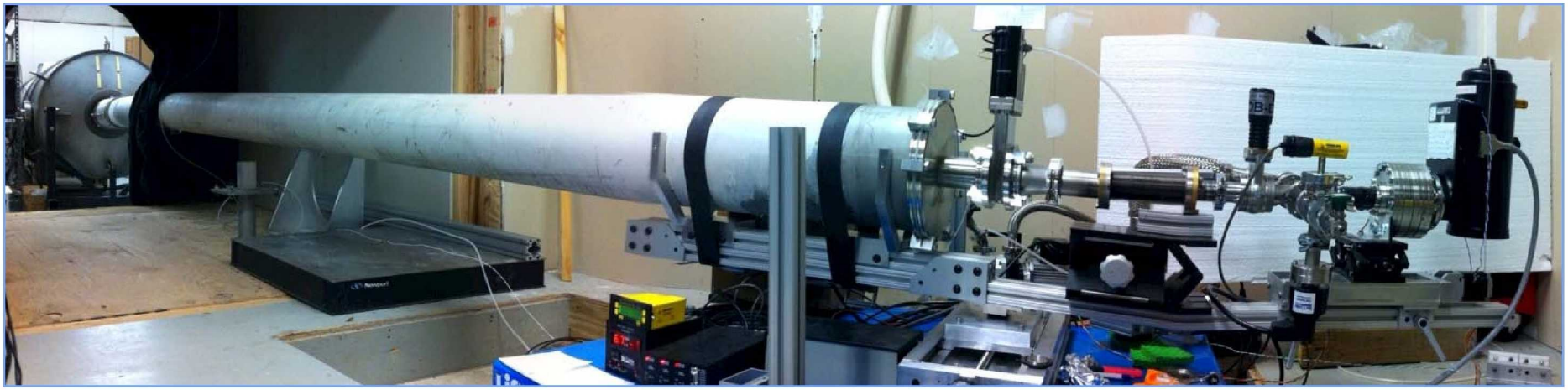
30° Permanent Bond Progress

- **Strongback GM11:**
  - Transferred mirror from top and bottom mounts on strongback (temporary) to side pin mounts on strongback (permanent) in front of interferometer with good results
- **Transferred 5 separate 30° mirrors from edge bonded strongbacks to Glass MHS**
- **6 temporary bonds per mirror**
  - Small amount of distortion noticed when permanently bonding side pins
  - Lots of distortion appeared when temporary bonds were broken
- **3 temporary bonds per mirror**
  - Lots of distortion appeared when permanently bonding side pins
    - Likely from structural instability of VAF, not bonding itself
  - More testing needed (only 1 trial complete)

X-Ray Test of Aligned and Permanently Bonded Mirror Pairs



- **Improved Area 200 X-Ray Facility**
  - Added reflective layer to roof to tighten temperature stability
  - Wired up new 4 DOF stage stack under MHS
  - Re-designed CCD detector platform to lower farther in order to accommodate mirrors in the frown orientation
- **Mirror pair bonded to single MHS structure and fixed relative to each other**
- **Tested robustness of kinematic mounts by removing and re-inserting MHS into chamber between X-ray tests**
- **Found that X-ray test results were very sensitive to temperature and cycled temperature to prove hypothesis**
- **X-Ray result under 10 arc-seconds HPD at 4.5 keV**
  - **The best image using the central 34° of the mirrors was 9.7”**
  - **The average image was 11.3” +/- 1.0” for a span of 9 images**



Milestones for 2011

- Making mirror substrates at ~3" HPD (two reflections) level, meeting IXO requirements
- Repeatably and consistently temp-bond mirror segments
  - Preserving figure
  - Stress free
- Repeatably and consistently align and permanently bond single pairs of mirror segments in mirror housing simulators (glass or titanium)
  - At 6 locations per mirror segment (flight-like bonds)
  - Obtain X-ray images at ~5" HPD (two reflections at 4.5 keV)
- Co-align and permanently bond 3 pairs of mirror segments (485P/S, 489P/S, and 494P/S)
  - At 6 locations per mirror segment (flight-like bonds)
  - Obtain X-ray images better than 10" HPD (two reflections at 4.5 keV)
- Define requirements and plans for demonstrating TRL-6
  - Description and definition of requirements
  - Establishment of budget and schedule for execution in subsequent years

Acknowledgements

M. Biskach[3], P.N. Blake, K.W. Chan[1], T. Evans[3], M. Hong[3], L. Kolos, J.M. Mazzarella[3], R. McClelland[3], L. Olsen[3], R. Petre, T.T. Saha, M. Sharpe[3], W.W. Zhang
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[3] Stinger Ghaffarian Technologies, Inc.

M.V. Gubarev, W.D. Jones, T. Kester, S.L. O'Dell
NASA Marshall Space Flight Center

D. Caldwell, W. Davis, M. Freeman, W. Podgorski, P.B. Reid, S. Romaine
Smithsonian Astrophysical Observatory

The work is supported in part by

NASA IXO Project Office

Goddard Space Flight Center Internal Research and Development Fund

A NASA Astronomy and Physics Research and Analysis (APRA) Grant

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